Neutrino masses and the structure of the weak gauge boson

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Abstract. The problem of neutrino masses is discussed. It is assumed that the electron neutrino mass is related to the structures and masses of the $W^{\pm}$ and Z^0 bosons. Using a composite model of fermions (described by the author elsewhere), it is shown that the massless neutrino is not consistent with the high values of the experimental masses of $W^{\pm}$ and Z^0. Consistency can be achieved on the assumption that the electron-neutrino has a mass of about 4.5 meV. Masses of the muon- and tau-neutrinos are also estimated.

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1. Introduction

The results of recent observations of atmospheric and solar neutrinos aimed at testing the hypothesis of the neutrino flavour oscillations [1, 2] indicate that neutrinos are massive. Although a very small, but non-zero neutrino mass, can be a key to new physics underlying the Standard Model of particle physics [3]. The Standard Model consider all three neutrinos (ν_e, ν_μ, and ν_τ) to be massless. Thus, observations show that the Standard Model needs some corrections or extensions.

So far, many models have been proposed in order to explain possible mechanisms for the neutrino mass generation [4]-[9], and many experiments have been carried out for measuring this mass. The experiments with tritium β-decay gave controversial results: the neutrino mass squared appears to be negative [10]-[12]. The current experimental constraints on the neutrino masses recommended by the Particle Data Group [13]:

- $\nu_e \leq 3 \cdot 10^{-6}\ MeV$
- $\nu_\mu \leq 0.19\ MeV$
- $\nu_\tau \leq 18.2\ MeV$.

are based on the averaged data from direct kinematic determinations of the neutrino mass. Astrophysical data [14] give stronger constraints:

$$\sum_i m_i < 1.8\ eV$$

for all species.

Recently a new composite model of fermions has been proposed by the author [15], in which the neutrino is described as a Majorana particle, almost massless in free states, but acquiring an essential mass if bonded to a charged particle. Our model satisfactorily (to an accuracy of 10^{-6}) reproduces masses of the fundamental fermions (quarks and charged leptons) but fails to predict masses of neutral particles, such as neutrinos or photons, as well as of the weak gauge bosons (Z^0 and $W^{\pm}$). Here we propose a possible solution of this problem by considering a hypothetical symmetry between the fermion and boson mass structures.

2. Possible structure of $W^{\pm}$

Our model is based on the idea of compositeness of fermions, supposing that they are formed of primitive entities with few properties (we refer to these entities as "preons"). The properties of the preon are limited to its three-colour symmetry known as SU(3), symmetry of charges, U(1), and mass. For simplicity, we use unit values for the preon mass and charge. Then masses of the composite particles (fermions) can be calculated as sums of the masses of their constituents (preons) if the composite particle is "rigid". Otherwise, the following formulae

$$m = \left| \frac{F}{a} \right| \tag{1}$$

and

$$F = -G\frac{MM'}{rr'} \tag{2}$$

can be used for the "non-rigid" structures. Here $M = \sum_{i=1}^{N} m_i$ is the sum of the component masses, N is the number of components, and $\frac{1}{M'} = \sum_{i=1}^{N} \frac{1}{m_i}$ is the reciprocal (reduced) mass of the composite system. Qualitatively, the particle is usually considered to be "rigid" if the combined effective potential of its constituents has a single minimum and "non-rigid" otherwise. In our model, the first family fermions appear to be rigid, while the fermions of the second and third families are rather clusters of particles.

Our model assumes a possibility of space inversion in the vicinity of the preon, with reciprocal distances r and $r' = 1/r$, measured from the preon's centre. By definition, $rr' = 1$. Assigning also unit values to the local acceleration ($a = 1$) and to the universal gravitational constant ($G = 1$), we obtain from (1) and (2) a simple formula for the fermion masses:

$$m = (\sum_{i=1}^{N} m_i)(\sum_{i=1}^{N} 1/m_i)^{-1}. \tag{3}$$

The masses in (3) are expressed in units of the preon's mass ($m_\Pi = 1$; Π stands for the preon). They can be converted into conventional units, say, proton mass units (m_p), by calculating m_p with (3) and dividing all other calculated masses by this value. The calculated masses can be also converted into MeV/c^2 by using a conversion factor $k_\Pi = 0.056777673$ $[MeV/\Pi]$ derived from the experimental fermion masses [15].

We structure the electron-neutrino as a closed loop composed of twelve preon triplets, each containing three preons of complementary colour charges. We denote this triplet with the symbol Y, recalling its geometrical configuration. The triplet has a mass of three preons, $m_{\mathsf{Y}} = 3$, and a charge $q_{\mathsf{Y}} = \pm 3$ preon units. In this notation, the structure of the electron neutrino can be written as $\nu_e = 6(\mathsf{Y}\overline{\mathsf{Y}})$. The charges and masses of the adjacent unlike-charged constituents of the neutrino are supposed to be mutually almost cancelled. The structure of the electron (positron) can be written as $e^- = 3\mathsf{Y}$ ($e^+ = 3\overline{\mathsf{Y}}$) with the resulting charge $q_e = \pm 9$ and mass $m_e = 9$ preon units ($9 \times k_\Pi = 0.511$ MeV). In our model, a neutral massless particle, if "rigidly" coupled to a charged particle, restores its mass. The mass of such a combined system will be equal to the sum of the masses of its components, and the charge will correspond to the charge of its charged component. For instance, the mass of the system $\mathsf{Y6(Y\overline{Y})}$ is the sum of $m_{\mathsf{Y}} = 3$ and 36 unit masses of the preons constituting ν_e ($m_{\mathsf{Y6(Y\overline{Y})}} = 39$ preon mass units). Its charge ($q_{\mathsf{Y6(Y\overline{Y})}} = -3$) corresponds to the charge of a single Y-particle. We associate the chain $(\nu_e\overline{\mathsf{Y}})\nu_e(\overline{\mathsf{Y}}\nu_e)$ with the *up*-quark. Its charge is equal to the charge of two $\overline{\mathsf{Y}}$-particles (+6) and its mass is the sum of two $m_{\mathsf{Y6(Y\overline{Y})}}$ ($39 + 39 = 78$ mass units or $78 \times k_\Pi = 4.42$ MeV). The *up*-quark combined with the structure $\mathsf{3Y6(Y\overline{Y})} = e\nu_e$ reproduces the *down*-quark, $\mathsf{3Y6(Y\overline{Y})}(\nu_e\overline{\mathsf{Y}})\nu_e(\overline{\mathsf{Y}}\nu_e)$, with its charge of $-9+3+3 = -3$ units and a mass of $9+36+78 = 123$ units ($123 \times k_\Pi = 6.98$ MeV).

The structure $\mathsf{3Y6(Y\overline{Y})} = e^-\nu_e$, which can be associated with the weak gauge boson, (see Table 2 in [15]) consists of 45 preons (9 preons of the electron and 36 preons of ν_e). It should have a mass of about 2.6 MeV within the structure of the d-quark, or zero (in a free state). In contrast, it is known that the experimental mass of the weak gauge boson is neither 2.6 MeV nor zero, but about 80 GeV. This indicates that expression (3) is not applicable to bosons. Even if one had taken $m_{\nu_e} \neq 0$, the mass of $W^\pm$ would increase very little, still disagreeing with experiment. We can resolve the problem by using a reciprocal formula

$$m = \Big(\sum_{i=1}^{N} m_i\Big)^{-1}\Big(\sum_{i=1}^{N} 1/m_i\Big) \tag{4}$$

for bosons, assuming symmetrical relationships between the boson and fermion mass structures. The physical justification for this assumption is not very strong: we suppose that the reciprocal manifestations of space introduced in [15] are interchangeable for fermions and bosons. But (4) reproduces the large $W^\pm$ and Z^0 masses. Actually, had the neutrino mass be taken zero, the masses of $W^\pm$ and Z^0 would become infinite. Using $m_{\nu_e} \neq 0$ in (4), one can calculate a verisimilar mass for the weak gauge boson, and the following electron-neutrino mass

$$m_{\nu_e} = (4.453 \pm 0.002) \cdot 10^{-3} \quad [eV] \tag{5}$$

corresponds to the experimental fit of $m_W = 80.43 \pm 0.04$ GeV [13], with the tolerance interval translated from m_W to m_{ν_e}.

3. The neutrinos ν_μ and ν_τ

In our model, the muon- and tau-neutrinos are hypothetically formed by consecutive additions of the unlike-charged pairs $\nu_e\mathsf{Y}$ and $\nu_e\overline{\mathsf{Y}}$ to the electron-neutrino. The muon-neutrino would have one such pair in its structure:

$$\nu_\mu = (\nu_e\mathsf{Y})\nu_e(\overline{\mathsf{Y}}\nu_e),$$

and the tau-neutrino has two such pairs:

$$\nu_\tau = (\nu_e\overline{\mathsf{Y}})\nu_e(\nu_e\mathsf{Y})\nu_e(\overline{\mathsf{Y}}\nu_e)\nu_e(\mathsf{Y}\nu_e).$$

Both ν_μ and ν_τ are parts of the tau-lepton, forming two components, $\mu\nu_\mu$ and ν_τ:

$$\tau^- = \underset{\boxed{1}}{(\overbrace{\nu_e e^-\overline{\mathsf{Y}}\nu_e\nu_e\nu_e\mathsf{Y}}^{\mu^-}\ \overbrace{\overline{\mathsf{Y}}\nu_e\nu_e\nu_e\mathsf{Y}}^{\nu_\mu})}\underset{\boxed{2}}{(\overbrace{\overline{\mathsf{Y}}\nu_e\nu_e\nu_e\mathsf{Y}\nu_e\overline{\mathsf{Y}}\nu_e\nu_e\nu_e\mathsf{Y}}^{\nu_\tau})}\,.$$

The clustered components of this structure are embraced in parenthesis and marked with the boxed numbers. The number of preons (mass) of the first component is

$$n_1 = m_1 = n_\mu + n_{\nu_\mu} = n_W + n_{\nu_\mu} + n_{\nu_\mu} = 45 + 78 + 78 = 201.$$

Using this value in (4) and taking into account the known experimental value for the muon mass

$$m_\tau^{exp} = m_2 = 1776.99^{+0.29}_{-0.26} MeV$$

($m_2 = 31297.33$ in preon mass units), one can translate m_τ^{exp} into the mass of ν_τ:

$$m_{\nu_\tau} = (9.0253^{+0.0018}_{-0.0011}) \cdot 10^{-3} \ [eV].$$

As for the muon-neutrino, it is more difficult to estimate its mass because there are no particles containing ν_μ as a separate component within their structures. For example, the muon can be structured as:

$$\mu^- = \underset{\boxed{1}}{(\overbrace{\nu_e e^-}^{W^-}\overline{\mathsf{Y}})}\underset{\boxed{2}}{(\nu_e\nu_e\nu_e\mathsf{Y})}$$

(see [15] for details), which includes ν_μ. But here it is shared between two components, $\boxed{1}$ and $\boxed{2}$, having its own substructure. Using the known experimental value for the muon mass: $m_\mu^{exp} = 105.658$ $[MeV]$ (1860.9168 preon mass units), we can do as much as to evaluate the upper limit for the muon-neutrino mass ($m_{\nu_\mu} \leq 0.68$ eV). But it should be more logical to suppose that m_{ν_μ} lies somewhere between the masses of the electron- and tau-neutrinos ($m_{\nu_e} = 4.4\, meV$ and $m_{\nu_\tau} = 9.0\, meV$), that is

$$m_{\nu_\mu} \approx 6 \cdot 10^{-3} \ [eV].$$

4. Structure of Z^0

The Z^0-boson is a photon-like particle with high mass. It is quite possible that its structure resembles that of $W^\pm$. We suppose Z^0 to be composed of W^+ and W^-:

$$Z^0 = \overbrace{\nu_e e^-}^{W^-}\overbrace{e^+\nu_e}^{W^+} \ . \qquad (6)$$

At a first glance, the component e^+e^- of this structure, (a neutral particle), should be massless. But in this case, the mass of Z^0 increases infinitely. Since the known experimental mass of Z^0 is finite ($m_Z = 91.1876 \pm 0.0021 GeV$ [13]), the mass of e^+e^- is:

$$m_{e^+e^-} = 0.90140 \pm 0.00004 \ [MeV],$$

in accordance with (4), (5) and (6), which means that the electron and positron wave functions in e^-e^+ are not overlapped. Of course, the e^+e^--particle can exist only for a very short period of time or at very low temperatures. Normally, the electron ($3\mathsf{Y}$) and its antiparticle ($3\overline{\mathsf{Y}}$) will decay into three structures $\mathsf{Y}\overline{\mathsf{Y}}$ (three photons).

5. Conclusions

The hypothetical symmetry between bosons and fermions in our model suggests a method for estimation of the neutrino masses. Our estimations agree with experiments but, being obtained for the neutrinos interacting with other particles ($W^{\pm}$ and τ), they should probably be considered as upper limits for the neutrino masses.

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